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The Clay Mineral Maps of Tripura and their Application in Land Use Planning

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Abstract : *Earlier exercise on the preparation of maps on clay minerals for some Indian states did not have the well-defined boundaries because of inadequate spatial data. Appreciating this as an important exercise for efficient management of natural resources, required research initiative has been made by the National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur to complete the task of generating clay mineral maps of different states. In this endeavour we generated various theme maps of clay minerals of Tripura. The clay samples (<2 μm) of the selected soil series were analyzed by X-ray diffraction (XRD) method and the clay mineral content was estimated using the X-ray diffractograms. The soil parameters such as cation exchange capacity, clay and organic matter contents were used to correlate the mineral make-up in the clay fractions. The data on clay minerals for 48 soil series were utilized to generate a clay mineral map for the state. It is interesting to note that most of the 2:1 clay minerals are interstratified ones which appear to have a close relation with the land use patterns in terms of forest, plantation and agriculture in the state.*

Key words : Clay minerals, maps, land use

Mapping natural resources with special reference to soil, based on factors of soil formation was initiated during fifties. The refinement of soil maps at various scales is still in progress. However, maps showing soil mineral compositions are generally rare (Ghosh and Bhattacharyya, 1982). This is notwithstanding with the fact that the knowledge of clay mineral composition of soils is of paramount importance in fertilizer use, crop management and for various land uses since the soil properties such as water retention and release, nutrient adorption and desorption, and shrink-swell behaviour are significantly influenced by the nature and content of soil clay minerals.

Investigation on soil mineralogy took a definite step forward after the use of X-ray diffraction (XRD) techniques. In India, Prof. J.N. Mukherjee, was the first to initiate XRD analysis of soil clays, at the Colloid Research Laboratory of Calcutta University. Work on soil mineralogy in India has been reviewed periodically by many (Mukherjee, *et al.,* 1971; Ghosh and Raychaudhuri, 1974; Ghosh and Kapoor, 1982; Ghosh, 1998; Pal *et al.,* 2000). However, no systematic effort has yet been made to develop soil clay mineral maps that could be linked to various land uses.

The present endeavour is a beginning of generating clay mineralogy maps of the Indian states with Tripura as a case study. We used geographic information systems (GIS) with the available information on clay mineral compositions (Ghosh and Bhattacharyya, 1982; Bhattacharyya, et al., 1996a,b; 2003a, b).

Study Area

Tripura

Tripura covers an area of 10.5 m ha with four districts showing mean annual temperature of 24°C and mean annual rainfall of 2065-2678 mm (Fig. 1) (Bhattacharyya et al., 1996). The state was surveyed at 1:50,000 scale. A total of 48 soil series were identified (Bhattacharyya, 1997a,b,c) with four soil orders and 43 mapping units (Fig. 2). Dataset generated through world bank aided rubber project (Bhattacharyya, 1996), DST funded project (Bhattacharyya, 2003a,b) on soil erosion (Bhattacharyya, 2004), and Soil Erosion Studies of the state (Bhattacharyya *et al.,* 2007) are used for the present study.

Methods

Field and laboratory data along with chemical and mineralogical data were used

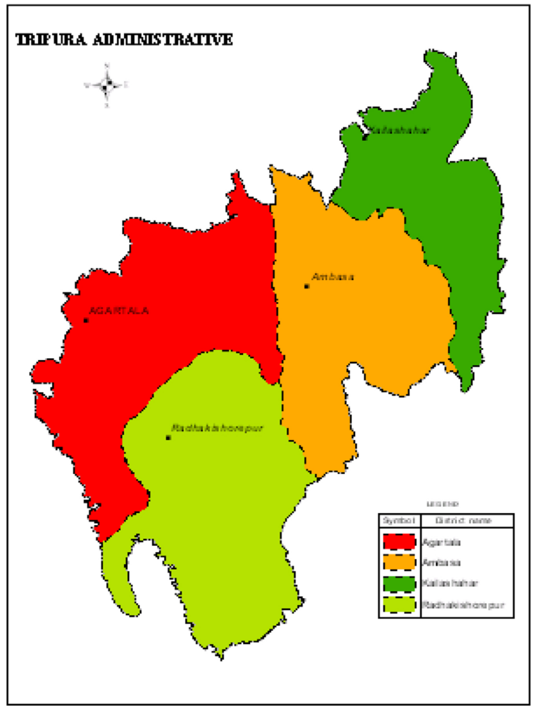

Fig. 1. *Tripura administrative map showing four different districts and their headquarters.*

to develop various GIS based thematic maps using ArcInfo (Ver 10.3). The methodology of generating the mineralogy map of the state is described in the following (Fig 3).

Results

Clay mineralogy of Tripura

The soil acidity varies from 4.1 to 4.4 (water) and 3.7 to 3.8 (*N*KCl). The ammonium acetate, soil CEC ranging from 5.6 to 7.0 cmol(+) kg^{-1} indicates that these soils are dominated by kaolinite. Conversion of soil CEC into clay show clay

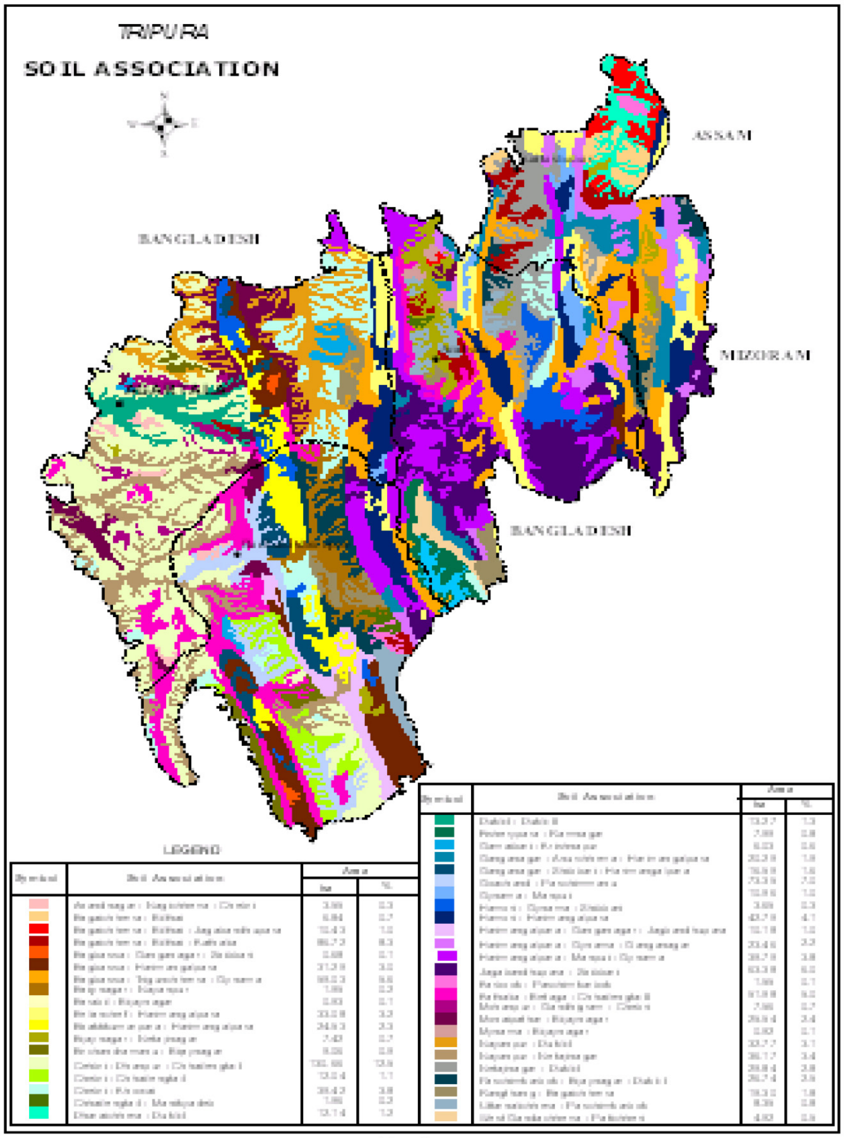

Fig. 2. *Soil series association map in Tripura*

CEC ranges from 11.0 to 16.0 cmol(+)kg^{-1} and suggests that these are low activity clay (LAC) soils. While estimating the minerals in various clay fraction using soil CEC we presume that CEC is largely contributed by clay and organic matter, and the CEC of humic acid, mica/hydroxy-interlayered smectite (M/HIS), HIS, hydroxy-

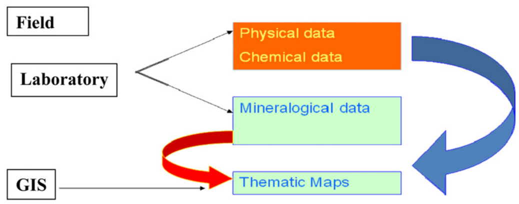

Fig. 3. *A schematic diagram of the methodology*

interlayered vermiculite (HIV), M/HIV and K/HIV were considered as 300, 40, 25, 30, 15 and 5 cmol(+)kg^{-1}, respectively.

Tripura soils were earlier divided into a few physiographic regions such as high-hill soils, medium-hill soils, tilla lands and flat lands. The relation between measured (following the above presumed values of different components of soils) and the estimated values of CEC was attempted for soils of the high hills, medium hills, tilla lands and flat lands (Figs. 4-7). In addition the same was attempted from the pooled data of all the soils analyzed for CEC vis-à-vis the measured values (Fig.8). But these efforts did not produce any encouraging datasets so we used the XRD generated mineralogical data. Representative XRDs of Belianchef and Hamori soils are shown in figures 9-10. The dominant minerals present are hydroxy-interlayer smectites (HISs), hydroxy-interlayer vermiculites (HIVs), mica- hydroxy-interlayer vermiculites (M/HIVs) and kaolinite-hydroxy-interlayer vermiculites (K/HIVs). On the basis of the semi-quantified values of these four minerals in the dominant soil series of Tripura representing different physiographic units various theme maps have been generated as shown in Figures 11-15.

The mineralogy maps developed were

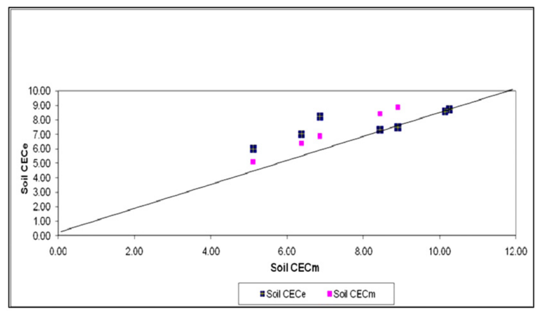

Fig. 4. *Comparison of soil CEC (m: measured and e: estimated) in high-hill soils in Tripura.*

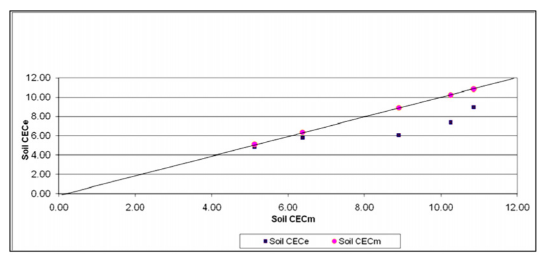

Fig. 5. *Comparison of soil CEC (m: measured and e: estimated) in medium-hill soils in Tripura*

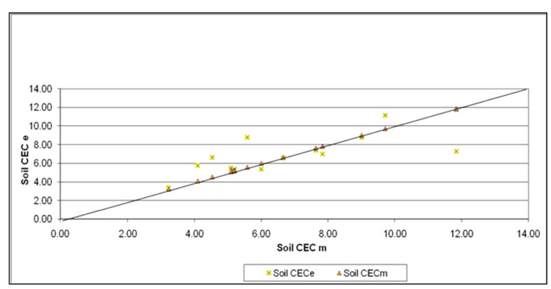

Fig. 6. *Soil CEC (m: measured and e: estimated) in Tilla lands, Tripura*

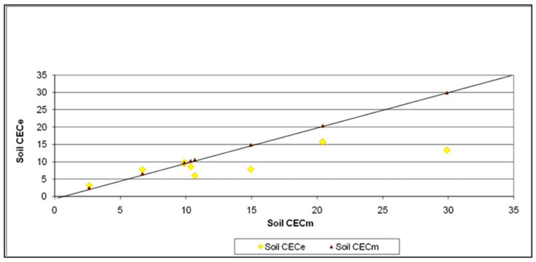

Fig. 7. *Soil CEC (measured and estimated) in Flood Plains, Tripura*

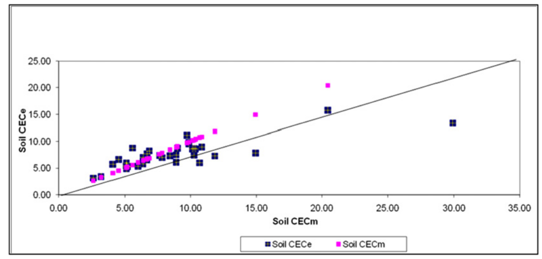

Fig. 8. *Soil CEC (m: measured and e: estimated) in Tripura*

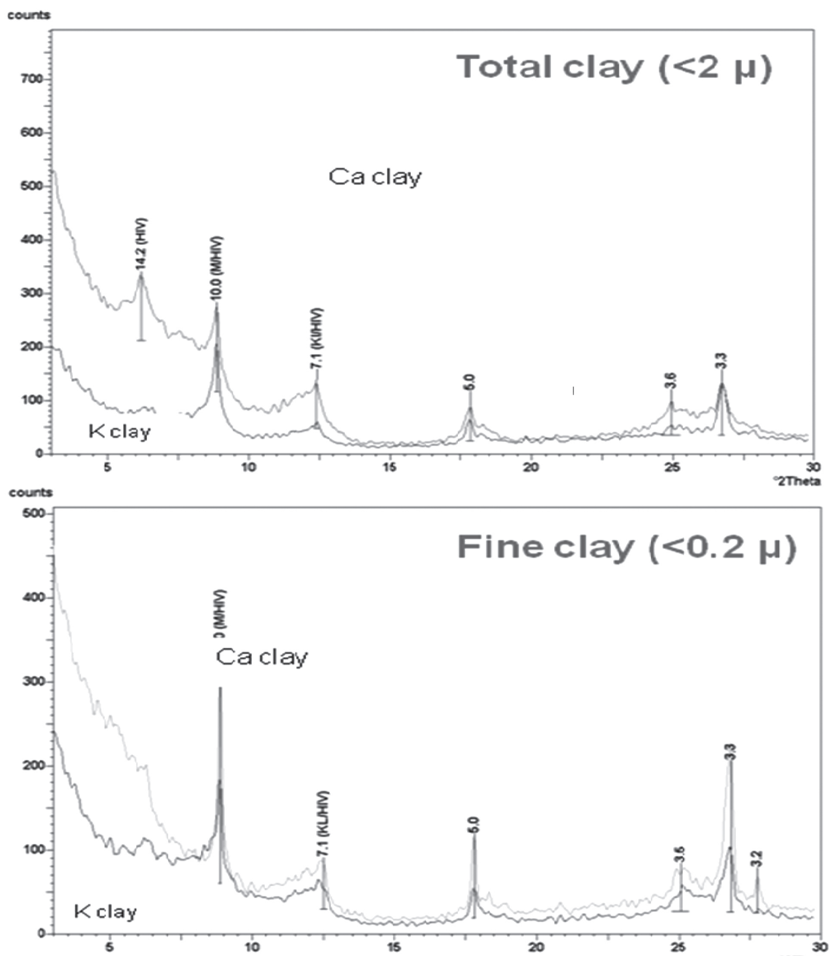

Fig. 9. *Representative X-ray diffractograms of total and final clay of Belianchef soils (Oxic Dystrudepts) (0-10 cm)*

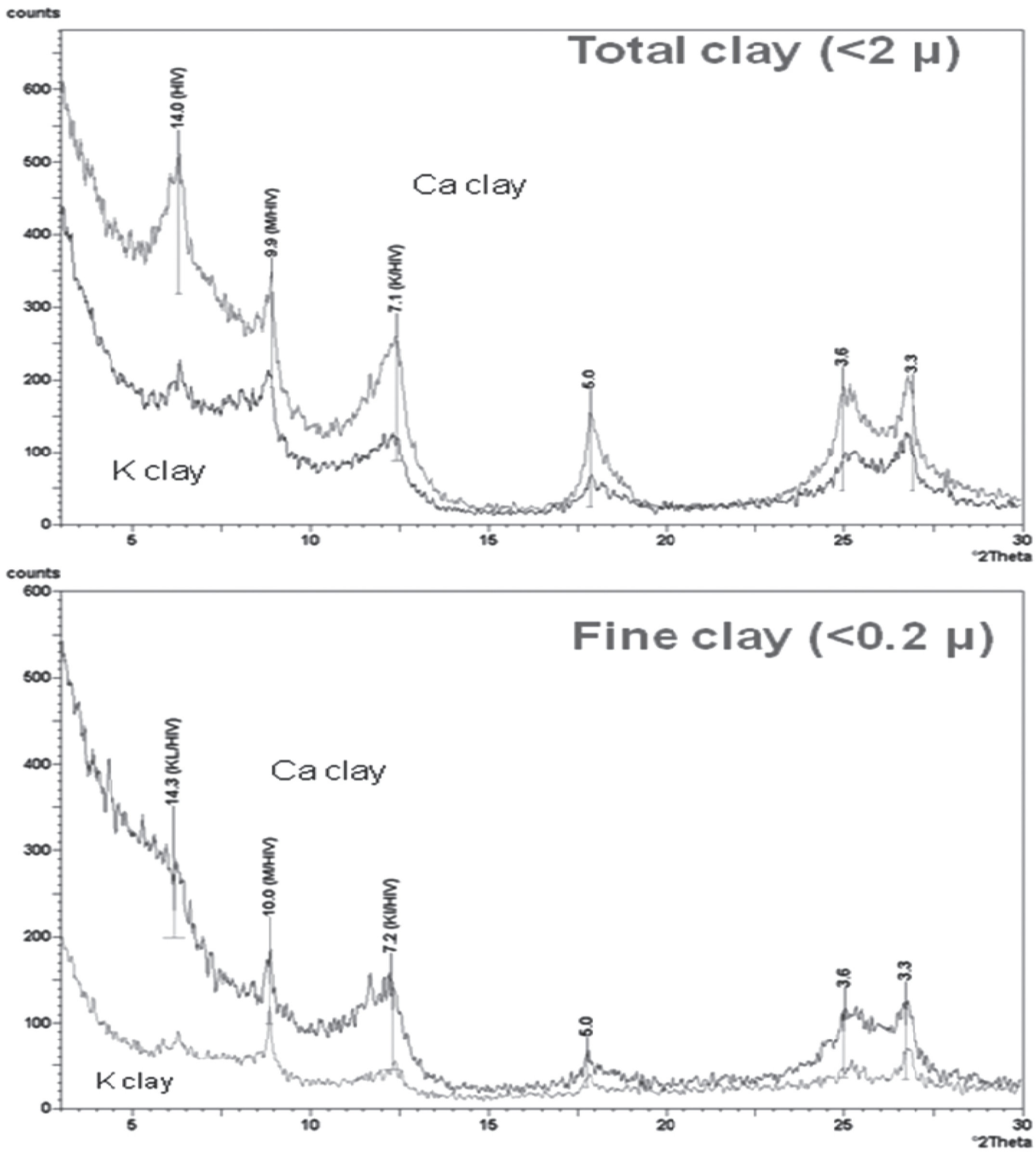

Fig. 10. *Representative X-ray diffractograms of total and fine clay of Hamori soils (Typic Haplustept) (0-10 cm).*

Fig. 11. *Distribution of hydroxyl-interlayered smectitie (HIS) in soil clays of Tripura*

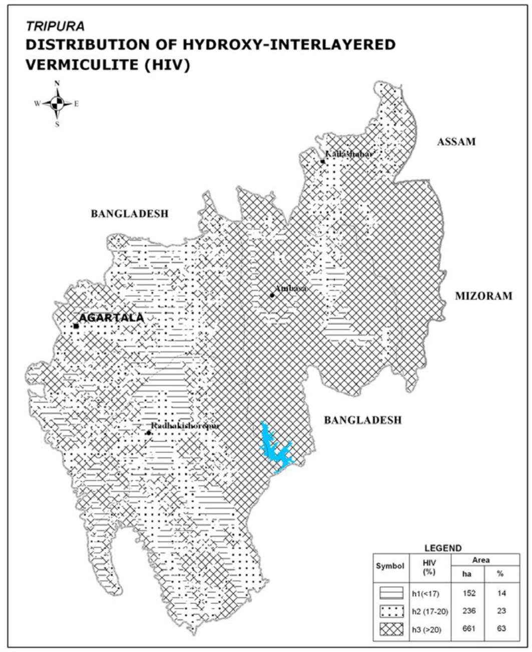

Fig. 12. *Distribution of hydroxy-interlayered vermiculite (HIV) in soil clays of Tripura*

compared with the crop models earlier prepared (Bhattacharyya *et al.,* 1996a,b; 2003a,b) and are now revised in this study. Figure 16 indicates similarity between distributions of hydroxy-interlayered vermiculite (HIV) with the distribution of suitability of rice-paddy. Traditionally, southern, western and interhill valleys are used for cultivating paddy in Tripura. We find most of the areas suitable for paddy are in the interhill valleys. The soils in these valleys showed the presence of hydroxy-interlayered vermiculite (HIV) as 17-21 per cent in the control section (0-100 cm soil depth). These HIV containing soils cover nearly 23 percent of the total geographical area of the state which is nearly similar to 30 per cent paddy growing areas of Tripura (Fig. 16).

While comparing suitability of rubber (*Hivea* species) we find a near similarity with the physiography (tilla lands) vis-à-vis rubber suitability (Bhattacharyya *et al.,* 1996a,b). In the humid tropical climate except a few patches in Tamil Nadu and Kerala, the other areas in southern and the north-eastern part of India including Tripura have been worked out as moderately suitable (S2). This fact assumes importance in view of the fact that *Hivea*, traditionally a tropical tree, experiences problem in the north-east (Tripura) due to cool winter days

Fig. 13. *Distribution of kaolinite/hydroxy-interlayered vermiculite (K/HIV) in soil clays of Tripura*

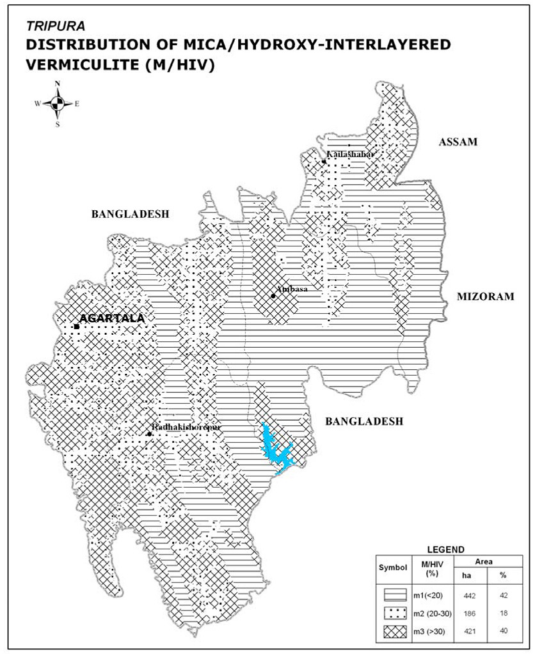

Fig. 14. *Distribution of mica/hydroxy-interlayered vermiculite (M/HIV) in soil clays of Tripura*

(Bhattacharyya 1997a,b,c) affecting latex formation. Mineralogical analysis indicates (Fig. 17) the Tilla lands suitable for rubber are represented by kaolinitic soils which also contain HIV minerals with<35 per cent kaolinite. In humid tropical weathering environment, presence of vermiculite/low charge smectites is common. This suggests that minerals in clay fractions have not yet reached the stage of kaolinites during humid tropical weathering where huge quantity of Al^{3+} ions are liberated to cause higher acidity. For Tripura soils total acidity (H^+) in 0-30 cm soil depth was worked out as 149 kg ha^{-1}. Estimation of amount of Al sequestered in surface soil (0-30 cm) for Tripura was estimated to be 65 kg ha^{-1} (Bhattacharyya, 2010). It is interesting to note that vermiculites and/or smectites adsorb these Al^{3+} ions to form hydroxy-interlayered vermiculites and hydroxy-interlayered smectites. These minerals in turn form interstratified minerals with kaolin as identified by the presence of Kl/HIV, Kl/HIS (Bhattacharyya, 2003a,b). These vermiculites thus act as a natural sink to sequester Al ions and thus keep the deleterious effect of Al-toxicity at bay. This is important since this finding explains a possible reason of better performance of

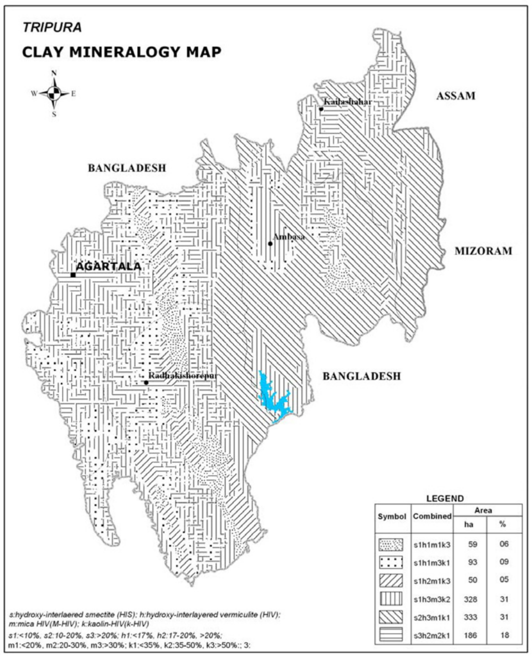

Fig. 15. *Clay mineralogy map of Tripura*

most of the plantation trees (coffee, tea, rubber, pineapple, cashew and a host of other horticultural crops) which are generally known as acid loving crops/trees. Besides, this finding has an implication in the measurement of lime requirement (LR) which is normally estimated on the basis of plough layer. Since roots of most of the perennial crops including commercial plantations penetrate deep into the soils, the soil depth for LR demands rethinking.

With the availability of mineralogical information of Tripura soils the earlier relation established (Bhattacharyya *et al.,* 2010) to link physiography on the landscape (elevation), chemical properties of soils

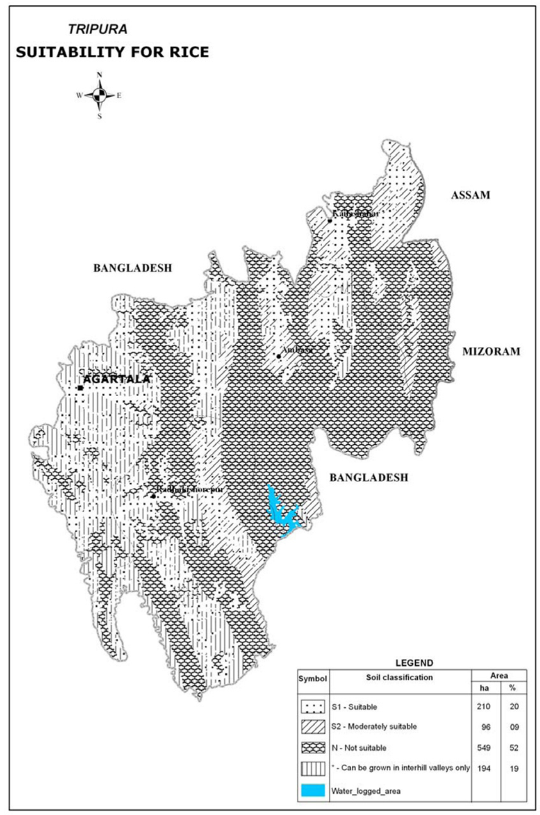

Fig. 16. *Suitability for rice in Tripura*

(KCl Extr-Al indicating degree of acidity vis-à-vis degree of Al-sequestration by minerals to reduce Al-toxicity) and different types of minerals stands for revision (Fig. 18). It is noticed that soils of higher elevation showing high to moderate Al contain mica, hydroxy-interlayered vermiculites as a dominant mineral where naturally occurring forests thrive. The tilla lands with moderate elevation showing very high Al are dominated by kaolinite, hydroxy-interlayered vermiculite, interstratified minerals and these lands are

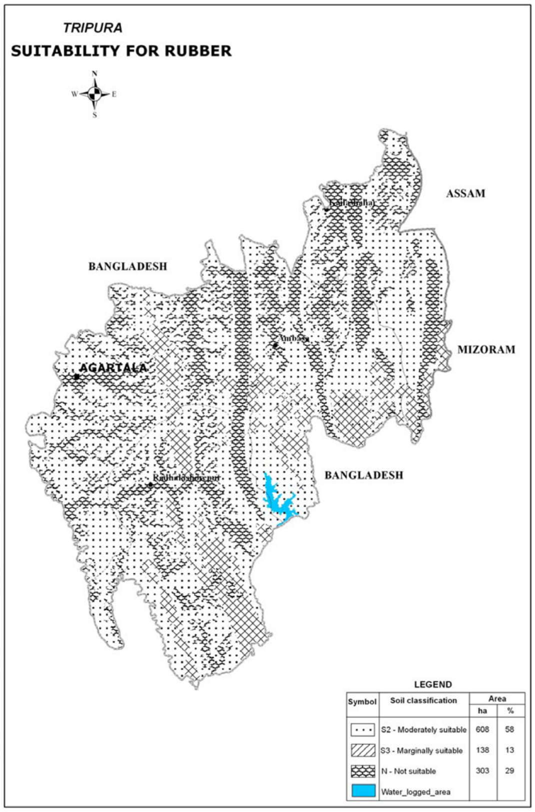

Fig. 17. *Suitability for rubber in Tripura*

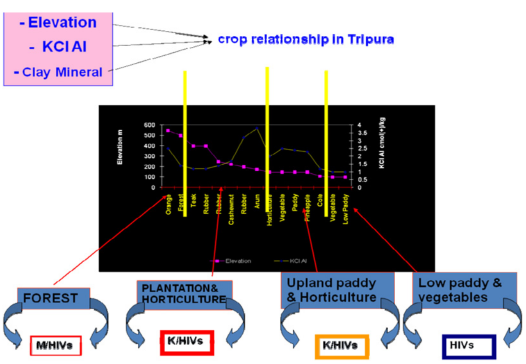

Fig. 18. *Relation between soil, site, mineralogy and land use in Tripura*

best suited for agriculture, horticulture and plantation. The landscape dominated by only hydroxyl-interlayered vermiculites at the low elevation in the valleys and interhill basins with very low KCl and Ext-Al are best suited for agriculture with paddy-rice and host of vegetables.

Conclusion

The present study on clay mineralogy map of Tripura initiated by the NBSS&LUP clearly projects a fact that such maps have practical implications in various land uses.

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